



# Transferring Color to Greyscale Images

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# The Problem

- **How to colorize greyscale images?**

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- **How to colorize greyscale images?**



- **Is his tie blue or green?**

# The Problem

- **How to colorize greyscale images?**



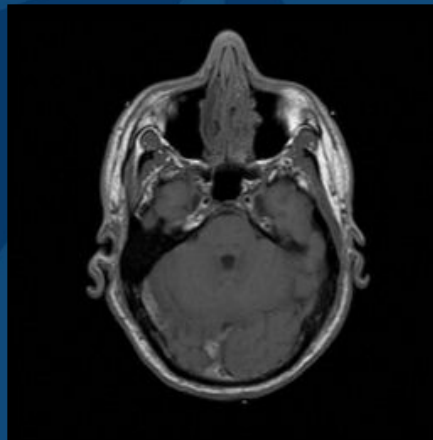
- **Red!!**

# The Problem

- **How to colorize greyscale images?**
- **Issues:**
  - **No “correct” solution**
  - **Need to be creative**
  - **How to minimize the manual labor involved?**

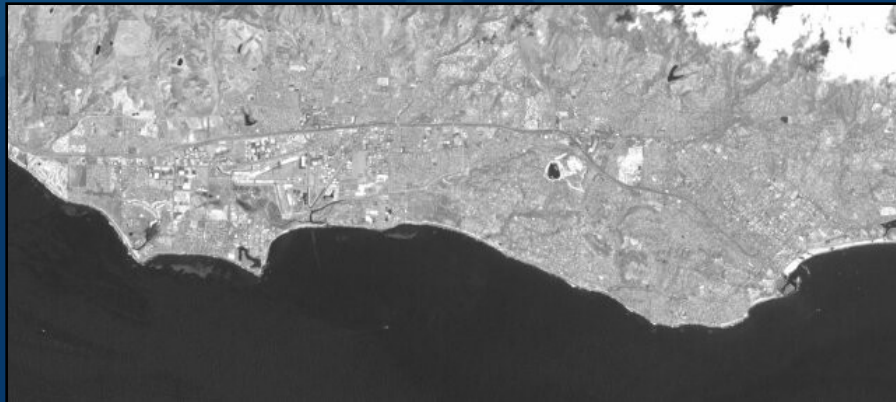
# Motivation

- Enhance Scientific Data
  - Medical Imaging (MRI, CT, X-Ray)



# Motivation

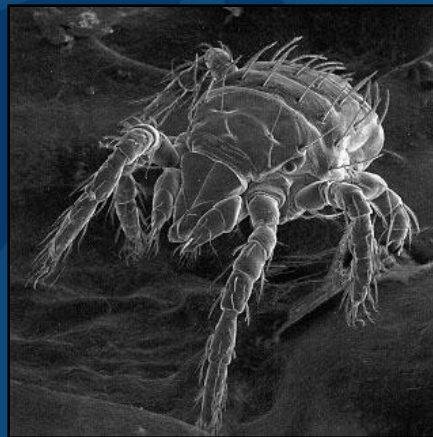
- Enhance Scientific Data
  - Medical Imaging (MRI, CT, X-Ray)
  - Satellite Images (Landsat)





# Motivation

- Enhance Scientific Data
  - Medical Imaging (MRI, CT, X-Ray)
  - Satellite Images (Landsat)
  - Scanning Electron Microscopy (SEM)



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- Enhance Scientific Data
  - Medical Imaging (MRI, CT, X-Ray)
  - Satellite Images (Landsat)
  - Scanning Electron Microscopy (SEM)
- Colorize black/white photographs and movies



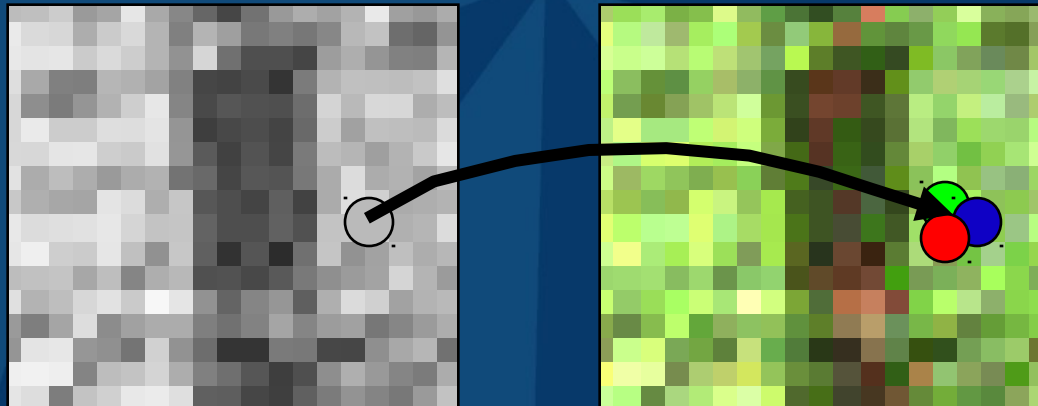
# Motivation

- Enhance Scientific Data
  - Medical Imaging (MRI, CT, X-Ray)
  - Satellite Images (Landsat)
  - Scanning Electron Microscopy (SEM)
- Colorize black/white photographs and movies
- Artistic Effects



# The Task

- The problem is fundamentally ill-posed
- It is an attempt to extrapolate from 1-D to 3-D
  - Map scalar luminance (intensity) to vector RGB



# Previous Methods

- Coloring Book Method
  - Photoshop: manually paint color with low opacity

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  - Movie Industry: track polygons [Cinesite Press Article]

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- Pseudo-coloring
  - Global Transformation/Color Map

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- Satellite Images
  - Registration [R2V Software], Orthoimagery [Premoze]



# Previous Methods

- Coloring Book Method
  - Photoshop: manually paint color with low opacity
  - Movie Industry: track polygons [Cinesite Press Article]
- Pseudo-coloring
  - Global Transformation/Color Map
- Satellite Images
  - Registration [R2V Software], Orthoimagery [Premoze]
- Image Analogies
  - Grey Source : Color Source :: Grey Target : Result

# Related Work

- “Color Transfer between Images”  
[Reinhard et al. 2001]



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- “Color Transfer between Images”  
[Reinhard et al. 2001]



Source

+



Target

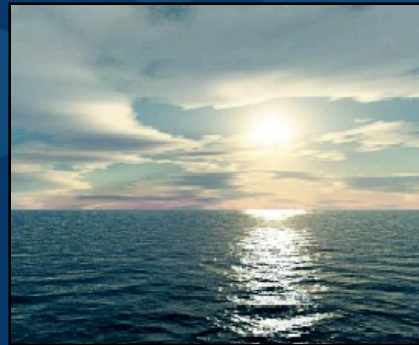
# Related Work

- “Color Transfer between Images”  
[Reinhard et al. 2001]



Source

+



Target

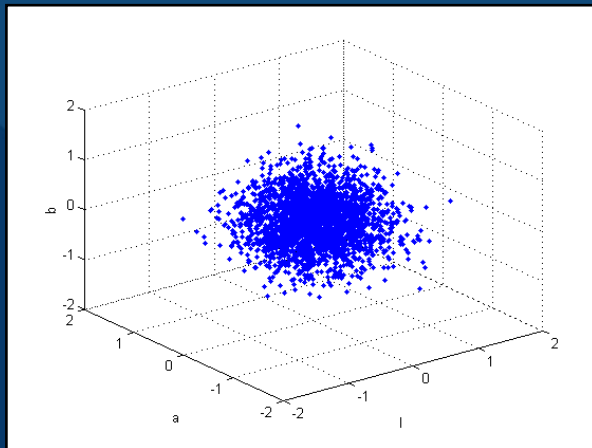
=



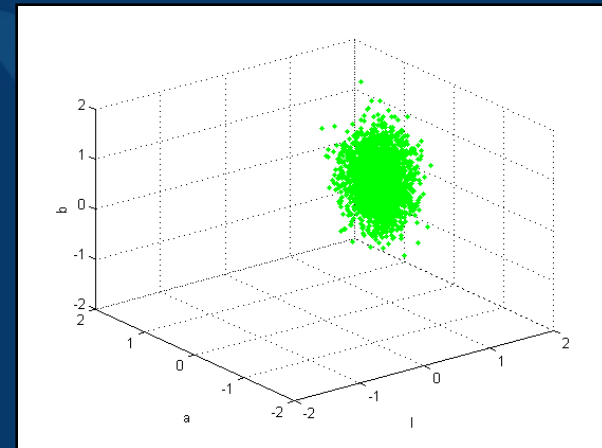
Final

# Reinhard et al.

- Decorrelated color space ( $l\alpha\beta$ ) [Ruderman et al., 1998]
- Scale and shift color distributions globally (Using mean and standard deviation)



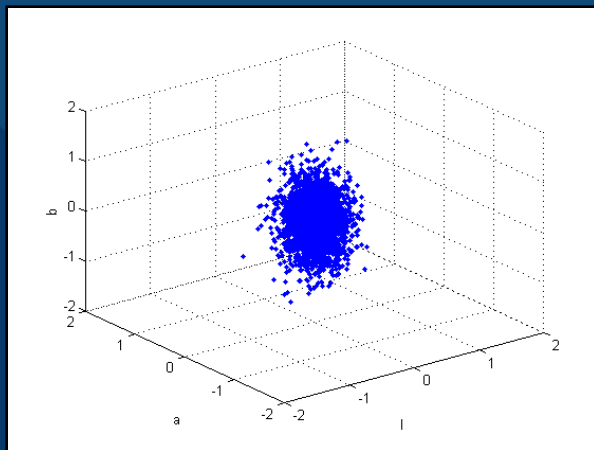
**Target**



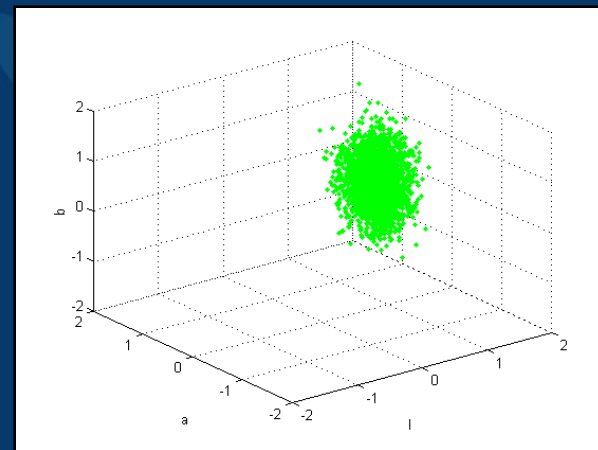
**Source**

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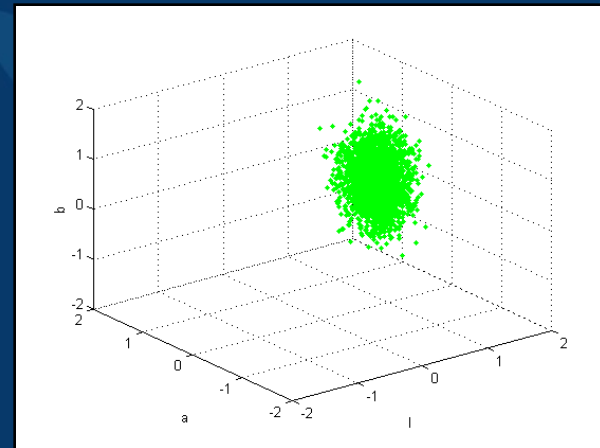
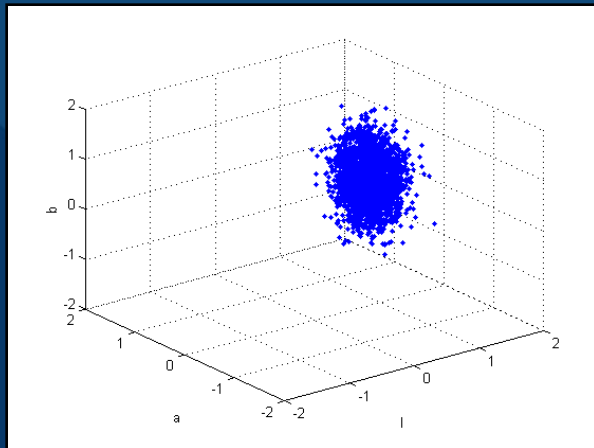
**Target (Scaled)**



**Source**

# Reinhard et al.

- Decorrelated color space ( $l\alpha\beta$ ) [Ruderman et al., 1998]
- Scale and shift color distributions globally (Using mean and standard deviation)



**Target (Scaled & Shifted)**

**Source**

# Our Approach

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**Target**





# Our Approach

Target

Source

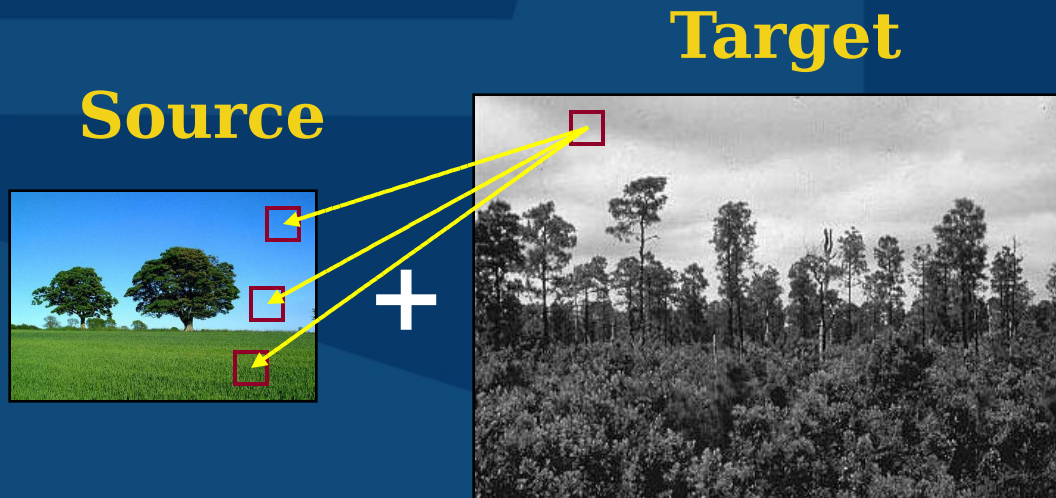


+



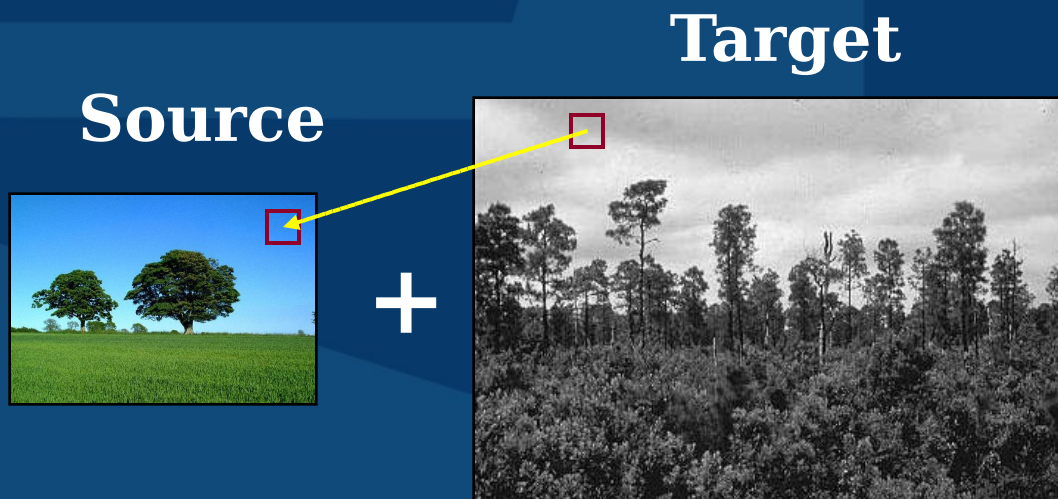
- Select color source image

# Our Approach



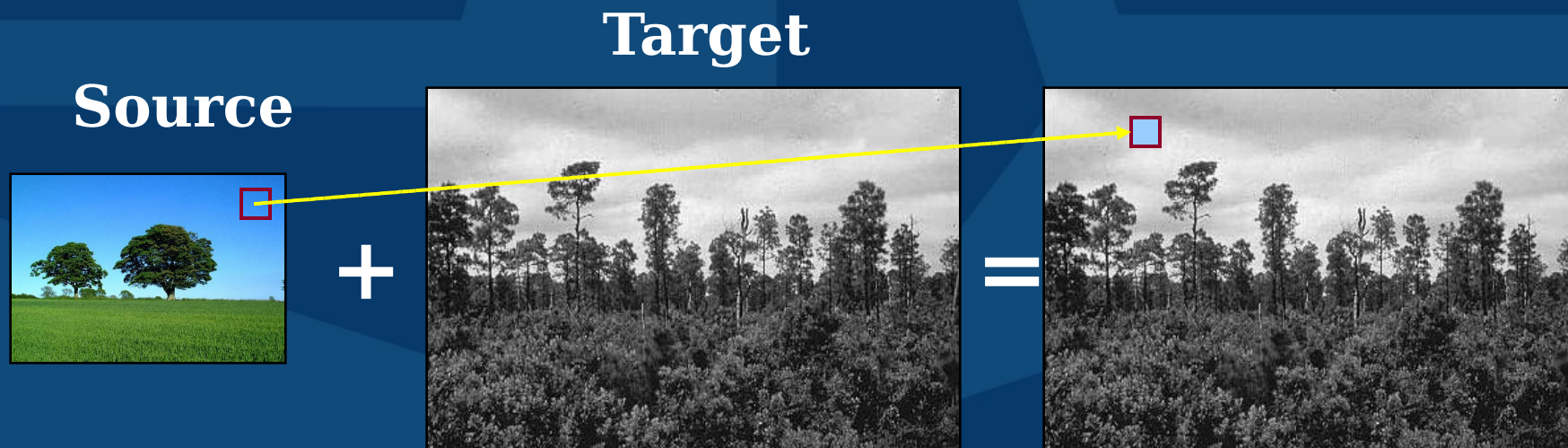
- Select color source image
- Match each target pixel with a few source pixels

# Our Approach



- Select color source image
- Match each target pixel with a few source pixels
  - Choose best match using local pixel neighborhood statistics

# Our Approach



- Select color source image
- Match each target pixel with a few source pixels
  - Choose best match using local pixel neighborhood statistics
- Transfer color



# Our Approach

**Source**



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**Target**



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**Final**



- Select color source image
- Match each target pixel with a few source pixels
  - Choose best match using local pixel neighborhood statistics
- Transfer color
- Repeat for all pixels

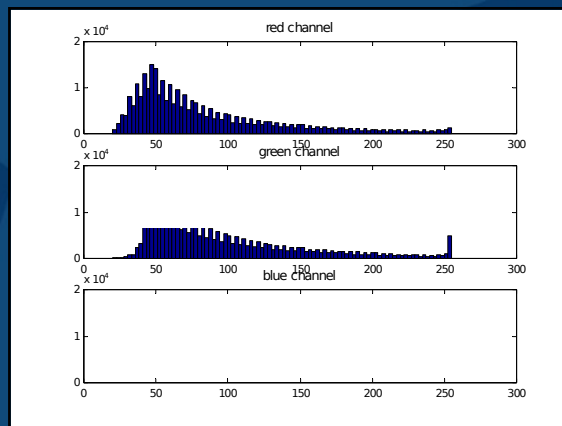
# Global Image Matching Procedure

1. Convert images to  $l\alpha\beta$  color space
2. Image Matching
3. Color Transfer

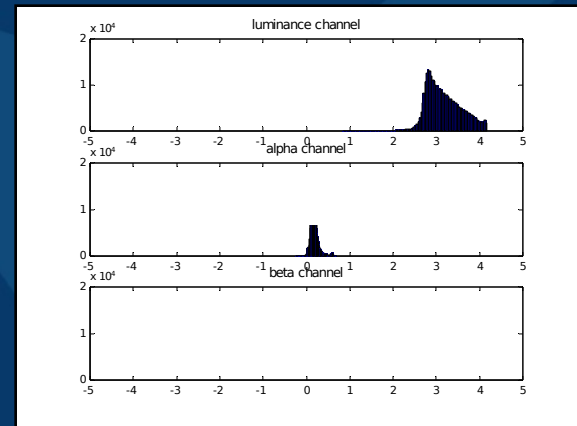
# 1. Convert to $l\alpha\beta$ Space

- Luminance ( $l$ ), alpha ( $\alpha$ ) and beta ( $\beta$ ) channels
- Minimizes correlation between axes (i.e. cross-channel artifacts)

Color  
Image



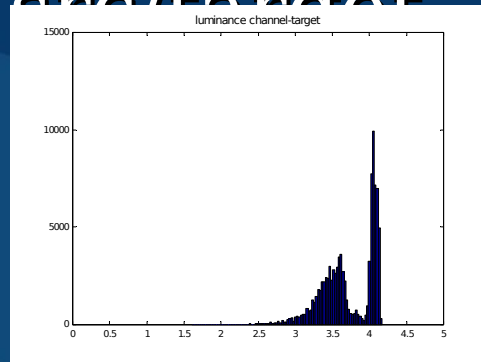
RGB



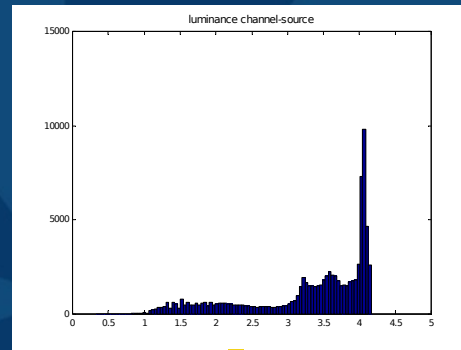
$l\alpha\beta$

## 2. Image Matching

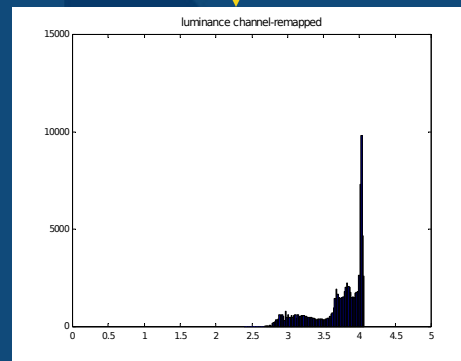
### 1. Remap luminance histograms between src/target



Target



Source-Before



Source-After



## 2. Image Matching

1. Remap luminance histograms between src/target
2. Precompute neighborhood statistics for images

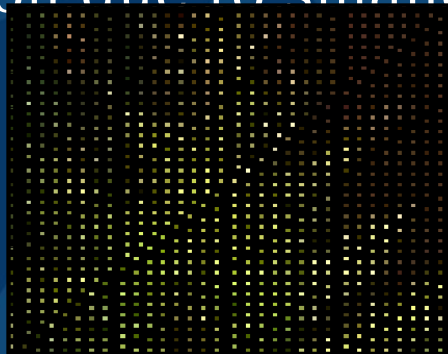
## 2. Image Matching

1. Remap luminance histograms between src/target
2. Precompute neighborhood statistics for images
3. Reduce samples using jittered sampling
  - Faster computation due to smaller search space



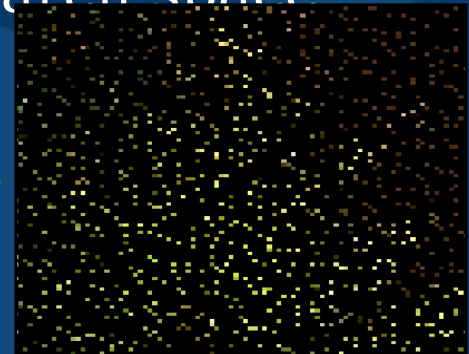
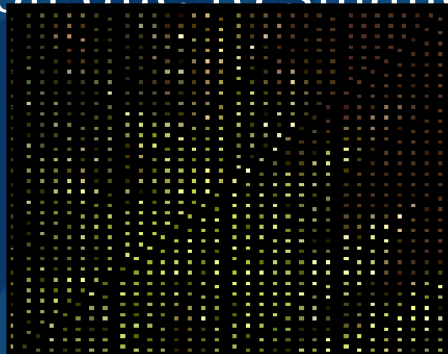
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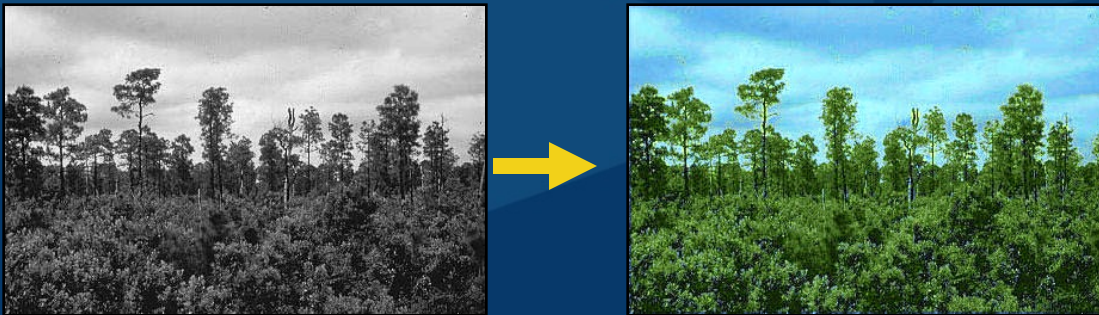


## 2. Image Matching

1. Remap luminance histograms between src/target
2. Precompute neighborhood statistics for images
3. Reduce samples using jittered sampling
  - Faster computation due to smaller search space
4. Find best neighborhood match from samples
  - Weighted metric of luminance, mean, standard deviation

## 3. Color Transfer

- Transfer only alpha and beta channels (color)



**Target Image Colorized Results**

## 3. Color Transfer

- Transfer only alpha and beta channels (color)
- The original luminance value remains unchanged



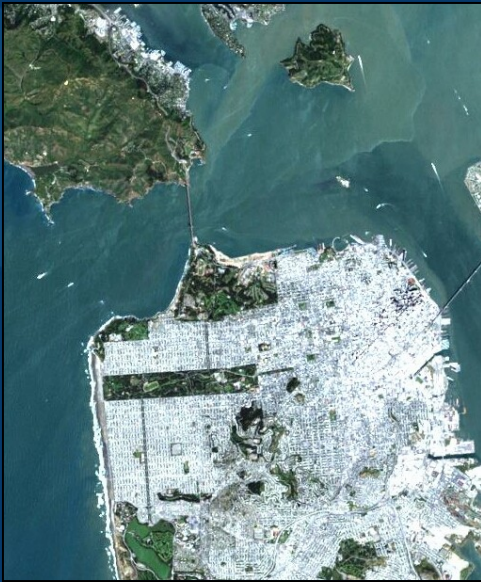
**Target Image Colorized Results**

**Convert to  
Greyscale  
(Photoshop)**

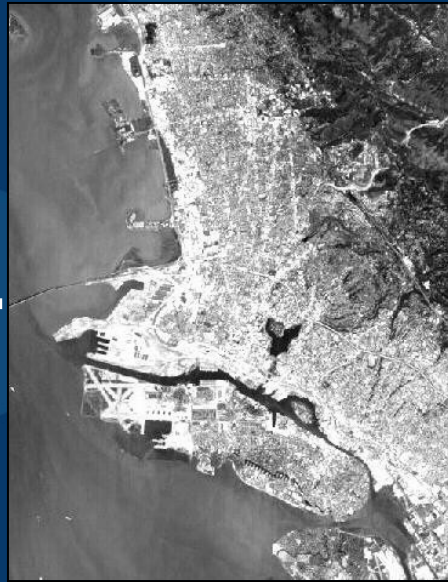


# Results: satellite

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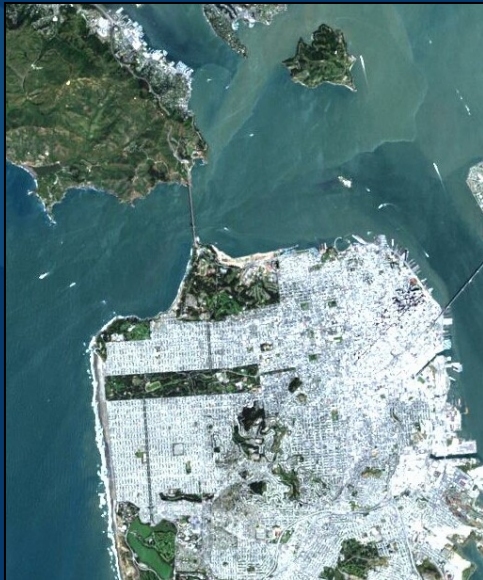
**Source**

**Target**



# Results: satellite

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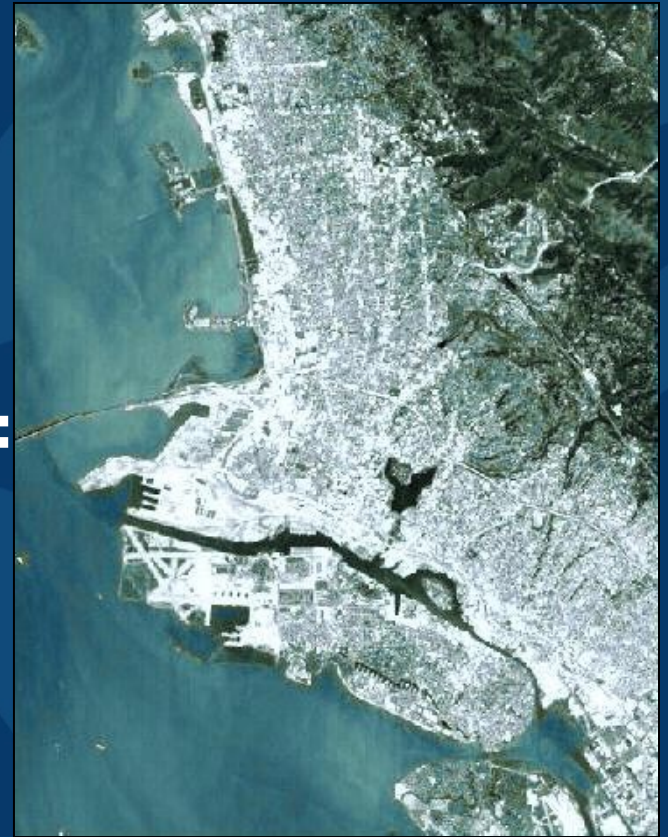
**Source**

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**Target**

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**Final**

# Results: Textures



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**Source**

**Target**



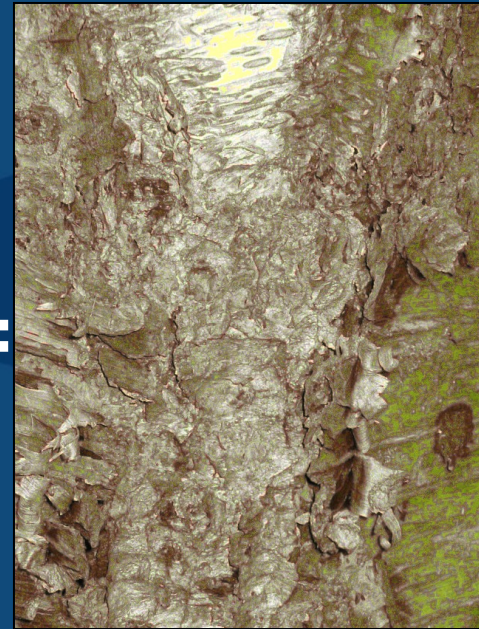
# Results: Textures



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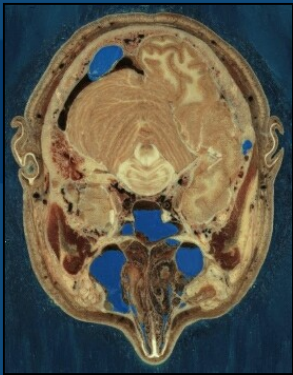
**Source**

**Target**

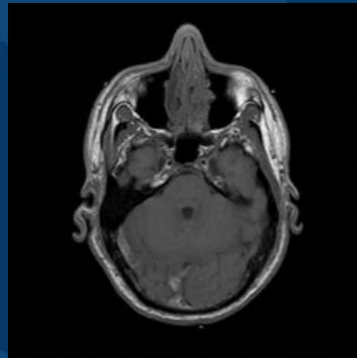
**Final**

# Limitations (Global Approach)

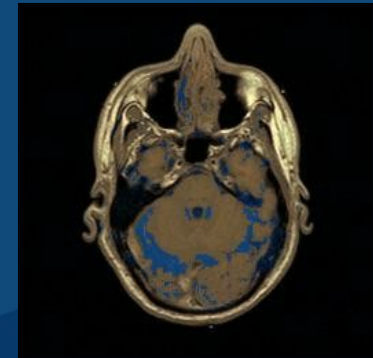
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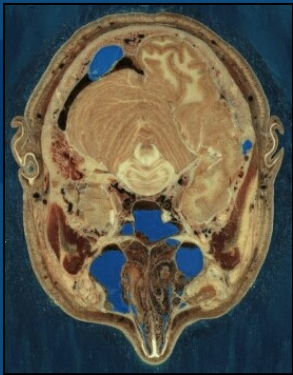
Source

Target

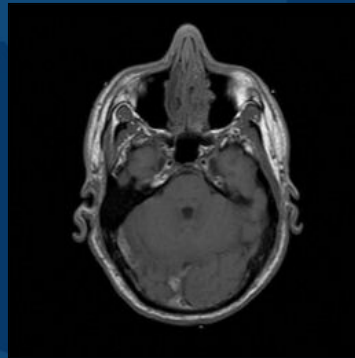
Final

# Limitations (Global Approach)

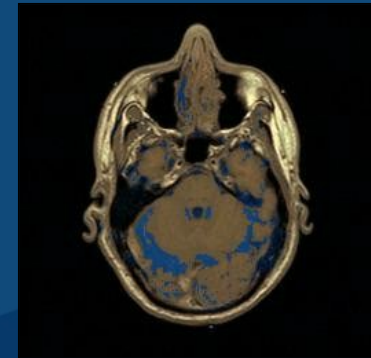
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**Source**

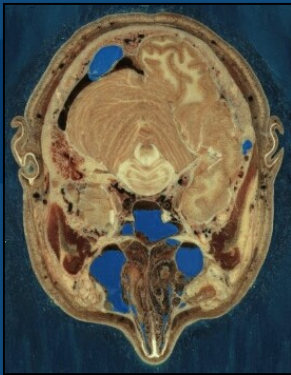
**Target**

**Final**

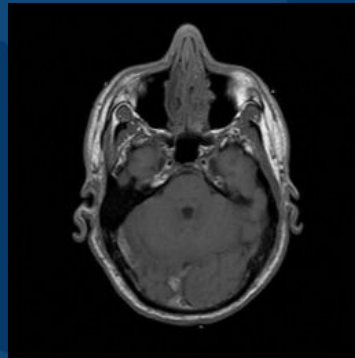


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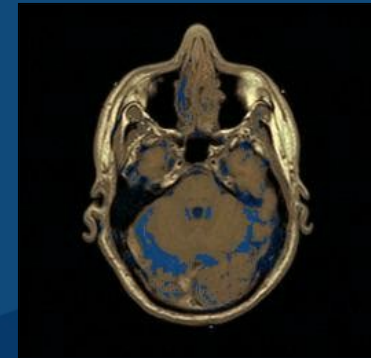
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**Source**

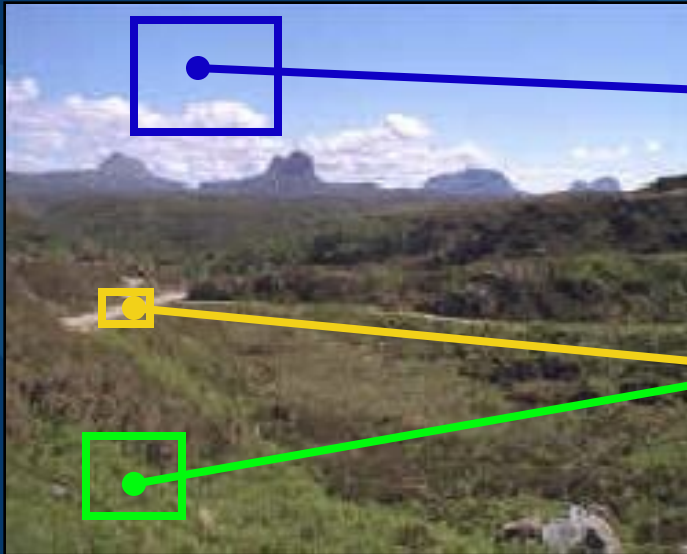
**Target**

**Final**

# User-Assisted Approach

1. User selects small number of swatches
2. Transfer color only to swatches  
(Global Matching Procedure)
3. Color entire target image  
(Only use swatch samples)

# 1. Selection of Swatches



**Source**



**Target**



## 2. Transfer Color to Swatches



- Transfer color using Global Matching Procedure (described previously)

# 3. Colorize Entire Image



- Discard original source image

# 3. Colorize Entire Image



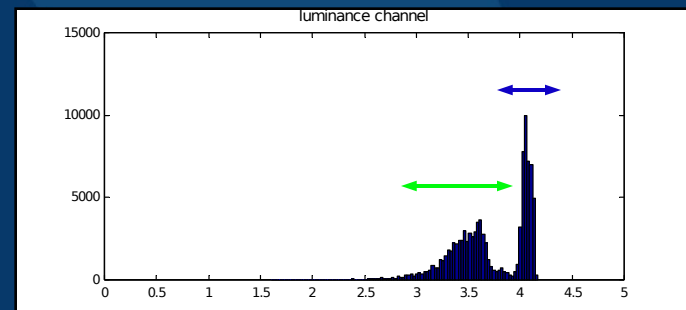
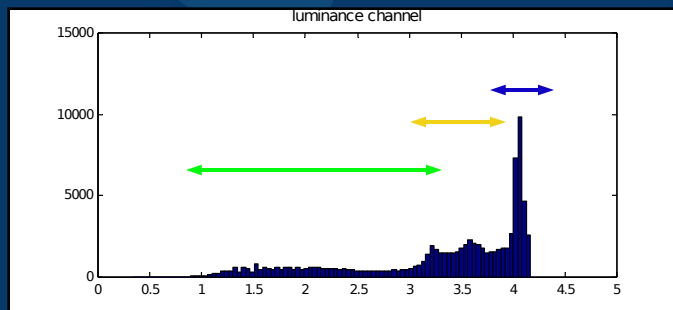
- Colorize the full image
  - Match using  $L_2$  Norm

# Swatches: Notes

- Expect good results *between* swatches

# Swatches: Notes

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# Swatches: Notes

- Expect good results *between* swatches
- Expect better matching within an image

(Allows more precise metric:  $L_2$  Norm)

$$L_2 = \sum ( \text{[Swatch 1]} - \text{[Swatch 2]} )$$



# Swatches: Notes

- Expect good results *between* swatches
- Expect better matching *within* an image

( $L_2$  Norm is more sensitive to image differences)



**Between Within**



**Between**



**Within**



# Results: Swatches

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**Source**

**Target**

**Final (Previous Method)**

# Results: Swatches

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Source

Target

Final

# Results: Swatches

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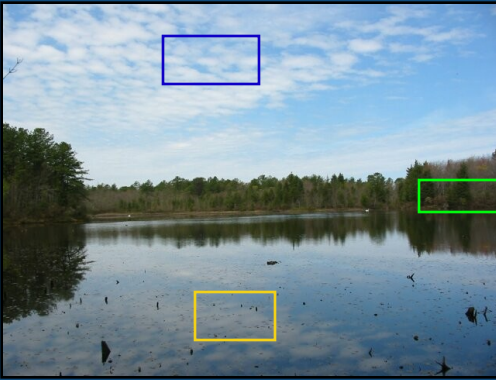
**Source**

**Target**

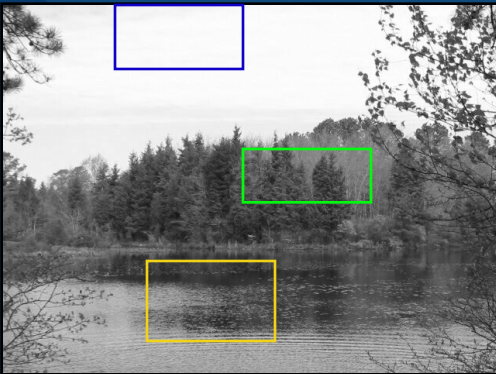
**Final**

# Results: Swatches

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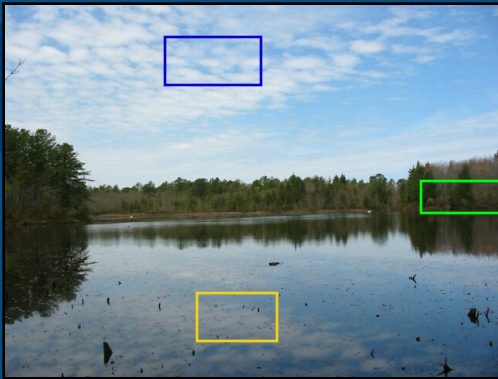
+





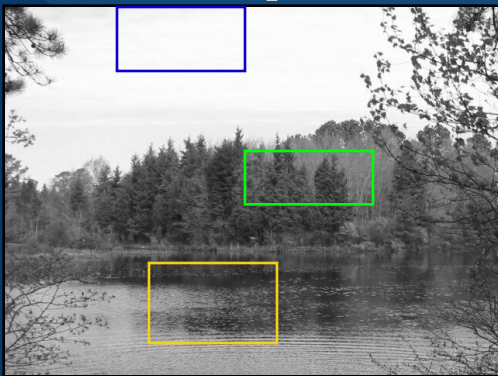
# Results: Swatches

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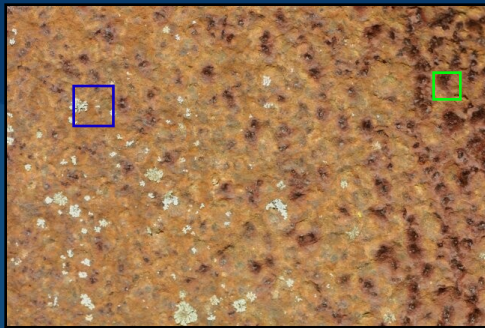
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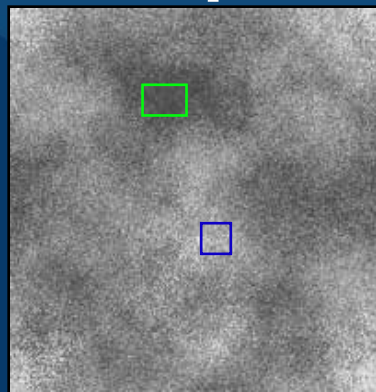
**Final**

# Results: Textures

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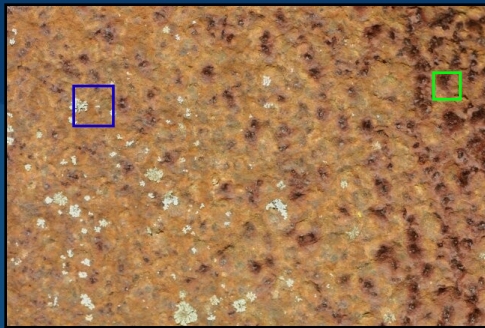
+





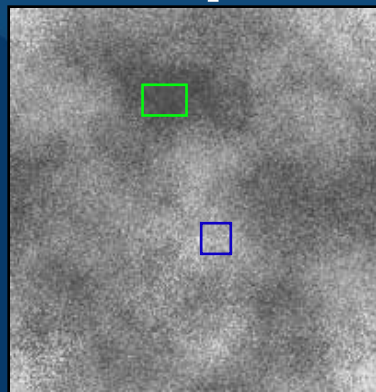
# Results: Textures

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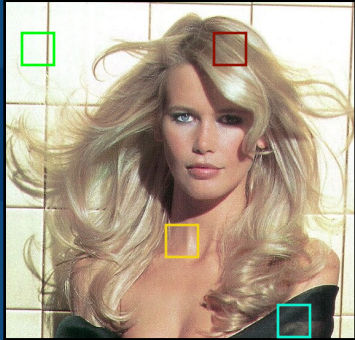


**Final**

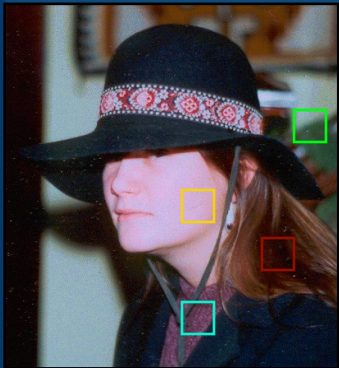


# Results: Swatches

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Source

Target

# Results: Swatches

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**Source**

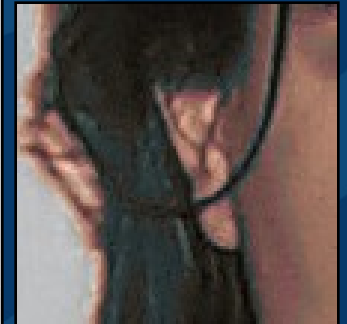
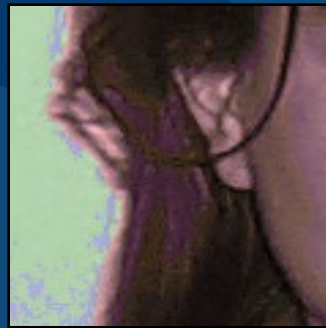
**Target**



**Final**

# Limitations

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# Comments

- Works well when *target* can be segmented well



# Comments

- Works well when *target* can be segmented well
- Large shadows present a problem
  - (partial volume effect)
- To be more useful, combine with other tools

# Running Time

- Pentium 3 (800 Mhz): 15 sec – 1 min
- Typical Image size: 640x480
- Implemented using MATLAB (Optimized)
- Factors:
  - Image size
  - Neighborhood Size



# Video

1. Colorize one frame using swatches
2. Use swatches to colorize the entire sequence

If a single frame in a sequence is colorized well, then the entire sequence can be colorized well



# Video Procedure

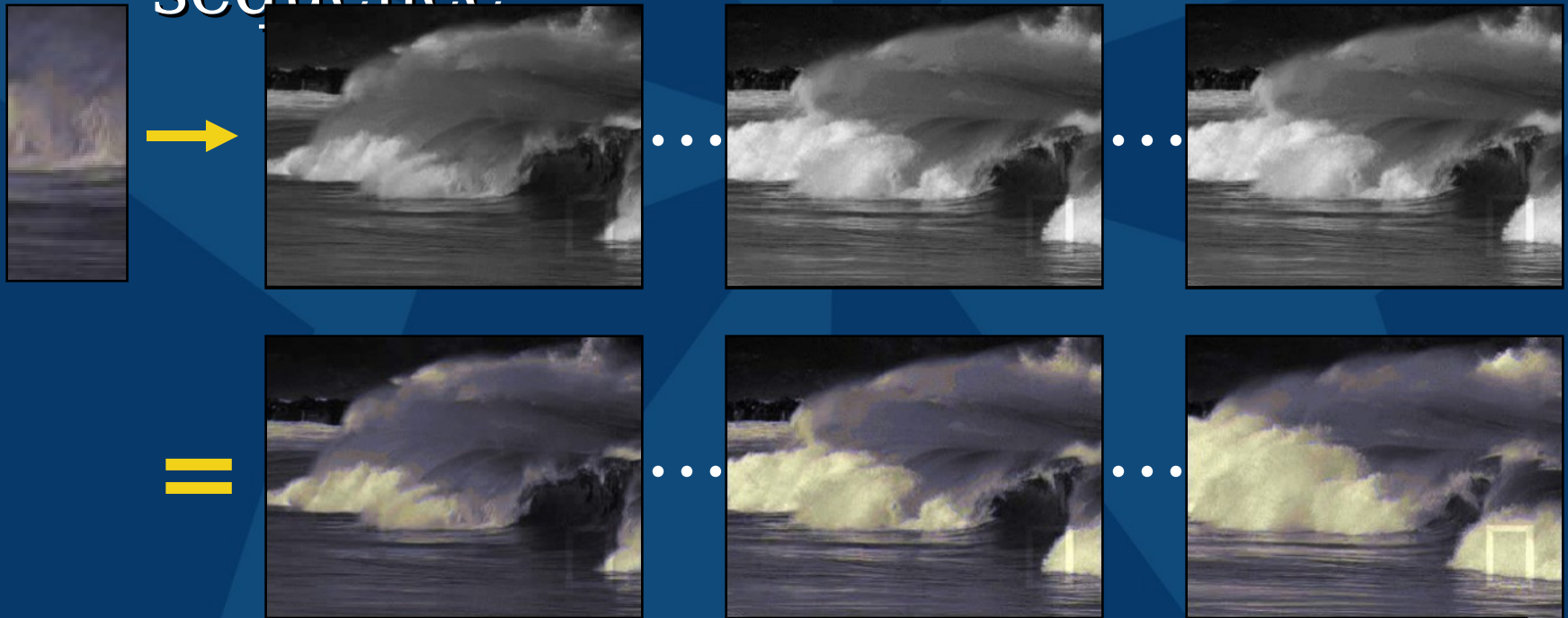
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## 1. Colorize one frame using swatches



# Video Procedure

1. Colorize one frame using swatches
2. Use swatches to colorize the entire sequence



# Video: Waves

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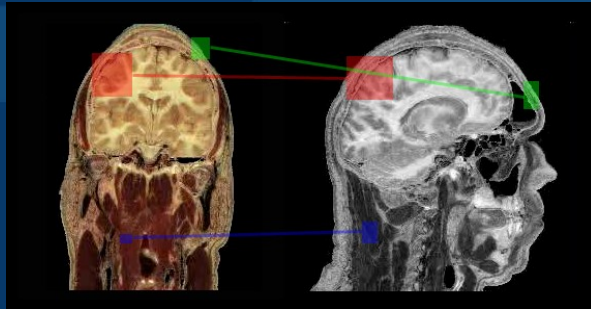
# Video: Horses

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# Video: Visible Human

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# Conclusions

- Keep original luminance values
- Use local pixel neighborhood statistics to match
- Simple algorithms provide fast (and good) results



# Future Work

- Robustness: more sophisticated matching
  - Multi-resolution, other pattern matching metrics
- Volumes
- Color Correction
  - Use local neighborhood statistics
  - Color correct movies automatically

# Questions?

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